

ENHANCED PROTECTION FOR INPUT BUFFERS OF LOW-VOLTAGE FLASH MEMORIES

Technical Field

5 The present invention relates generally to semiconductor integrated circuits. More particularly, it pertains to devices and methods to protect input buffers of low-voltage flash memory devices.

Background

10 A transistor is a device that controls the flow of electrons. This ability to control the flow is important in that information, in the form of electricity, may be processed or stored by the transistor. To process or store greater amounts of information, transistors can be collected together to form an integrated circuit. An example of an integrated circuit that processes information is a central processing
15 unit (CPU), which can be likened to the computing aspect of the human brain. Another example of an integrated circuit, which can be likened to the memorizing aspect of the human brain, is a memory device for storing information. A computer comprises these two core integrated circuits—CPU and memory.

20 Memory devices have progressed from early designs, which consumed considerable power because of the need to continuously refresh the memory, to present devices, which are more desirable because of their frugal use of power. Presently, memory devices include low-voltage transistors. These low-voltage transistors use a voltage supply that is about 1.8 volts. Supplying too great a voltage to these low-voltage transistors, either by accident or design, would detrimentally
25 affect the lifetime of these transistors.

 - Yet, voltage supplies larger than 1.8 volts exist in memory devices that include low-voltage transistors. Memory devices need these voltage supplies by design to perform memory operations, such as reading, programming, or erasing. In

the event that a low-voltage transistor receives by accident an electrostatic discharge, voltages on the order of several thousand volts may undesirably enter and ruin the transistor. Such a lack of resistance by low-voltage transistors to higher voltages may lead to an eventual lack of acceptance in the marketplace for products based on memory devices that include such low-voltage transistors.

5 Thus, what is needed are devices and methods to inhibit the semiconductor breakdown that affects the lifetime of low-voltage transistors.

Summary of the Invention

10 The above mentioned problems with low-voltage transistors and other problems are addressed by the present invention and will be understood by reading and studying the following specification. Devices and methods are described which accord these benefits.

15 In one illustrative embodiment, a system is discussed to enhance buffering low-voltage flash memory. The system includes a multiple of thin gate-oxide transistors and an input buffer. The input buffer is receptive to an enabling signal, an input signal, and an inhibiting signal. The input buffer further includes a component that inhibits semiconductor and/or oxide breakdown of the plurality of thin gate-oxide transistors when the inhibiting signal is at a low voltage level.

20 In another illustrative embodiment, an input buffer for a low-voltage flash memory device is discussed. The input buffer includes an input stage and an output stage. The input buffer optionally includes a voltage sensor and an inhibiting circuit. The input stage has a transistor that includes a gate, a drain, and a source. The gate is receptive to an inhibiting signal. The drain is receptive to an input
25 signal. The transistor inhibits the input signal from being presented at the source when the inhibiting signal is at a first predetermined level. The output stage has an inverter that includes first and second connections. The first connection is coupled to the source of the transistor. The second connection presents the input signal to

the low-voltage flash memory device. The voltage sensor triggers when the input signal is at a second predetermined level. The voltage sensor is receptive to a pumped signal and the input signal. The inhibiting circuit selectively produces the inhibiting signal. The inhibiting circuit is receptive to a pumped signal and a sensed signal.

5 Another illustrative embodiment includes a method for buffering a low-voltage flash memory device. The method includes transferring and outputting. The act of transferring is executed by an input stage having a gate, a drain, and a source. The gate of the input stage is receptive to an inhibiting signal. The drain of
10 the input stage is receptive to an input signal. The input stage inhibits the input signal from being presented at the source when the inhibiting signal is at a predetermined level. The act of outputting is executed by an output stage by inverting by an inverter. The inverter includes a first connection and a second connection. The first connection is coupled to the source of the input stage. The
15 second connection presents the input signal to the low-voltage flash memory device.

These and other embodiments, aspects, advantages, and features of the present invention will be set forth in part in the description which follows, and in part will become apparent to those skilled in the art by reference to the following description of the invention and referenced drawings or by practice of the invention.
20 The aspects, advantages, and features of the invention are realized and attained by means of the instrumentalities, procedures, and combinations particularly pointed out in the appended claims.

Brief Description of the Drawings

25 Figure 1 is a block diagram of a system according to an embodiment of the present invention.

Figure 2 is a circuit diagram according to an embodiment of the present invention.

Figure 3 is a circuit diagram according to an embodiment of the present invention.

Figure 4 is a circuit diagram according to an embodiment of the present invention.

5 Figure 5 is a block diagram according to an embodiment of the present invention.

Detailed Description

In the following detailed description of the invention, reference is made to the accompanying drawings which form a part hereof, and in which is shown, by way of illustration, specific embodiments in which the invention may be practiced. In the drawings, like numerals describe substantially similar components throughout the several views. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilized and structural, logical, and electrical changes may be made without departing from the scope of the present invention.

15 The transistors described herein include transistors from bipolar-junction technology (BJT), field-effect technology (FET), or complementary metal-oxide-semiconductor (CMOS) technology. A metal-oxide-semiconductor (MOS) transistor includes a gate, a first node (drain), and a second node (source). Since MOS is typically a symmetrical device, the true designation of "source" and "drain" is only possible once voltage is impressed on the terminals. The designations of source and drain herein should be interpreted, therefore, in the broadest sense.

20 The terms "high" and "low" as used herein refer to V_{cc} ; the voltage supply, and ground, respectively. The term "external supply" as used herein refers to V_{cc} , the voltage supply. In one embodiment, the voltage supply supplies a voltage in the range of 1.65 to 2.22 volts, unless otherwise indicated.

25 The term "energy-storing device" described herein includes any devices capable of storing charges. The term "energy-storing device" includes a capacitor.

The capacitor described herein can be any capacitor fabricated on an integrated circuit using any fabrication technique. The energy-storing device described herein, however, may be fabricated as either an n-channel transistor or a p-channel transistor; the transistor's source and drain are connected together to form one
5 conductive plate, its gate forms the other conductive plate, and the oxide layer forms the dielectric.

The term "pre-charging device" described herein includes any devices capable of providing charges to maintain a predetermined level of charges in an energy-storing device while a system that includes the energy-storing device is
10 turned off. The reason for pre-charging is thus: the energy-storing device may have to store a large amount of charges to enable a charge pump circuit to provide a high-voltage signal. Without pre-charging, an undesired amount of time may have to be taken once the system is turned on to charge the energy-storing device. The pre-charging device described herein can be a square-law device. The pre-charging
15 device described herein can be any transistor fabricated on an integrated circuit using any fabrication technique. The pre-charging device described herein, however, may be fabricated as an n-channel transistor with its drain and gate connected together; the drain is connected to an external supply.

The term "charging device" described herein includes any devices capable of
20 charging an energy-storing device up to the level of the external supply. The purpose of the charging device is to charge the energy-storing device to compensate for any level degradation that may occur from the pre-charged process. The charging device described herein can be any transistor fabricated on an integrated circuit using any fabrication technique. The charging device described herein, however,
25 may be fabricated as an n-channel transistor. This transistor may be configured with its drain connected to an external supply.

The term "metal option" described herein includes a conductor that can be inserted to close a circuit or removed to open a circuit. Such a conductor may be

inserted or removed at any appropriate time, such as after prototype fabrication, so as to obtain a desired circuit behavior.

5 The embodiments of the present invention focus on the problem of inhibiting semiconductor breakdown of low-voltage transistors that have thin gate-oxides. The term "semiconductor breakdown" means the inclusion of oxide breakdown. Digital circuits, such as flash memory, favor metal-oxide-semiconductor field-effect transistors (MOSFET) because of the digital nature of these transistors. MOSFETs are either on or off to symbolize the digits 0 or 1 depending on the voltage that is presented at the gate. Such a voltage helps to create an electric field that controls the digital state of a MOSFET.

10 One component of the MOSFET that is essential for creating the electric field is the gate-oxide. The gate-oxide acts like a dielectric to create a barrier between electrical charges with opposite polarity so as to maintain the electric field. As with most dielectrics, the gate-oxide has a certain dielectric strength. If the strength of the electric field created by the voltage at the gate is greater than the dielectric strength, the gate-oxide will breakdown, and the lifetime of the transistor is compromised.

20 The marketplace prefers handheld products that are based on low-voltage integrated circuits, such as flash memory, because such products use less power and therefore last longer. Handheld products need to store information, and low-voltage flash memory is chosen as a storage medium. Low-voltage flash memory uses a voltage supply of about 1.8 volts. To obtain the same speed as previous generations of transistors, which use a voltage supply of about 3.3 volts, the low-voltage flash memory includes transistors having gate-oxides of about 40 angstroms in thickness. Such a width is thinner than the width of gate-oxides of previous generations of transistors and is therefore more susceptible to high voltages.

25 Low-voltage flash memory that includes thin gate-oxide transistors also uses other transistors with varying requirements in voltage supplies: medium voltage,

high voltage, and super high voltage. Flash memory needs these varying voltage supplies in order to operate the memory cells, such as in reading, programming, and erasing. In one aspect of the invention, a certain high voltage may be applied to the flash memory in order to transition the flash memory to a test mode. As discussed
5 above, the thinner gate-oxide presents a problem for transitioning the flash memory to a desired test mode.

Another problem is the presence of electrostatic discharge. Electrostatic discharge is a transfer of electrostatic charge between bodies at different electrostatic potentials that is caused by direct contact or induced by an electrostatic
10 field. Electrostatic discharge may transfer a voltage on the order of several thousands of volts to a low-voltage transistor having a thin gate-oxide. If such a voltage is presented to the thin gate-oxide, the transistor having such a gate-oxide may be ruined.

The embodiments of the present invention solve these and other problems.
15 The embodiments of the present invention are now discussed below.

Figure 1 is a block diagram of a system according to an embodiment of the present invention. System 100 includes an input buffer C102. In one embodiment, the system 100 enhances the buffering of low-voltage flash memory. The input
20 buffer C102 acts to inhibit semiconductor breakdown of transistors having thin gate-oxides. Such an inhibition occurs when certain voltages are presented to the input buffer C102. In one embodiment, these certain voltages include voltages having an undesired high voltage level. The input buffer C102 is receptive to an enabling
signal S102, an input signal S104, and an inhibiting signal S110.

The enabling signal S102 is connected to ground via a resistor R102. In one
25 embodiment, the resistor R102 is about 2.4×10^3 ohms. The input signal S104 is a signal presented at an input pin of an integrated circuit that embodies the system 100. Other circuits, which will be described hereinafter, generate the inhibiting signal S110. The inhibiting signal S110 helps the input buffer C102 to inhibit

undesired voltages from entering the system 100 to ruin transistors having thin gate-oxides. In one embodiment, such inhibiting occurs when the inhibiting signal S110 is at a low voltage level.

5 The input buffer C102 presents the input signal S104 as signal S112. The signal S112 enters an inverter I102. The inverter I102 presents an inverted signal S112, called signal S114, to other circuits following the system 100. In one embodiment, such other circuits include circuitry of a flash memory device.

10 The system 100 includes a voltage sensor C104. The voltage sensor C104 is receptive to the input signal S104 and a pumped signal S106. A charge-pump circuit (not shown) generates the pumped signal S106. In one embodiment, the pumped signal S106 includes a voltage of about 5 volts.

The voltage sensor C104 monitors the input signal S104. When the input signal S104 reaches a desired high voltage level, the voltage sensor C104 triggers. The triggering of the voltage sensor C104 produces sensed signal S108 at a certain voltage level; otherwise the sensed signal S108 is produced at another voltage level. 15 The sensed signal S108 reflects whether the voltage sensor C104 has been triggered. The sensed signal S108 is presented to an inhibiting circuit C106.

The inhibiting circuit C106 selectively produces the inhibiting signal S110. The inhibiting circuit C106 is receptive to the sensed signal S108 and the pumped signal S106. When the sensed signal S108 reflects that the voltage sensor C106 has 20 been triggered, the inhibiting circuit C106 produces the inhibiting signal S110 at a level that causes the input buffer C102 to inhibit the transfer of the input signal S104. Such an inhibition prevents the input signal from entering the system 100.

25 Figure 2 is a circuit diagram according to an embodiment of the present invention. The input buffer 200 represents an implementation of the input buffer C102 as discussed in Figure 1 above. The input buffer 200 is receptive to an input signal S204; this input signal S204 is similar to the input signal S104 as discussed hereinbefore. The input signal S204 is presented to node A.

A first clamping circuit C202 couples to the node A. The first clamping circuit C202 clamps the input signal S204 to the voltage supply, which is about 1.8 volts. A second clamping circuit C202 also couples to the node A. A second clamping circuit C204 clamps the input signal S204 to ground. These two clamping circuits, C202 and C204, help to overcome an electrostatic-discharge test that is applied to an integrated circuit, such as a low-voltage memory device that includes the input buffer 200. In one embodiment, the electrostatic-discharge test is a test that complies with EIA/JEDEC standards. These standards include EIA/JEDEC, Test Method A114-A: Electrostatic Discharge (ESD) Sensitivity Testing Human Body Model (HBM) (October 1997) and EIA/JEDEC, Test Method A115-A: Electrostatic Discharge (ESD) Sensitivity Testing Machine Model (MM) (October 1997).

A resistor R202 couples to the node A. The resistor R202 acts to limit current that accompanies the input signal S204 having a high voltage, such as when the input signal S204 is from an electrostatic discharge. In one embodiment, the resistor R202 is about 1.106×10^3 ohms. The resistor R202 also couples to a node B. The input signal S204 having passed through the resistor R202 from node A is presented at node B.

The input buffer 200 includes an input stage T202 having first, second, and third connections. In one embodiment, the first connection can be considered the gate, the second connection considered the source, and the third connection considered the drain. Thus, the input stage T202 can be considered a transistor having a gate, source, and drain. In one embodiment, the input stage T202 is an n-channel transistor.

The source of the input stage T202 couples to node B and therefore is receptive to the input signal S204 that is presented at node B. The drain of the input stage T202 presents the signal S204 at node C depending on the voltage level of the inhibiting signal S206 presented at node E. Thus, the input buffer 200 is receptive

to the inhibiting signal S206; this inhibiting signal S206 is similar to the inhibiting signal S106 as discussed hereinbefore. The gate of the input stage T202 couples to node E.

5 In the embodiment in which the input stage T202 is an n-channel transistor, the input stage T202 transfers the input signal S204 from the source at node B to the drain at node C. This occurs when the inhibiting signal S206 presents a high voltage at node E. In the same embodiment, the input stage T202 inhibits the input signal S204 from the source at node B to be transferred to the drain at node C. This occurs when the inhibiting signal S206 presents a low voltage at node E.

10 This behavior of the input stage T202 enables it to inhibit undesired voltages from entering an integrated circuit, such as a flash memory device, to ruin low-voltage transistors having thin gate-oxides. Such an inhibition occurs in at least two circumstances. First, when an integrated circuit is inactive, the inhibiting signal S206 presents a low voltage level at the gate and thereby the input stage T202
15 inhibits the input signal S204 at the source from being transferred to the drain. Suppose that during handling of a flash memory device, an electrostatic discharge accidentally occurs. Because the flash memory device is inactive, the input stage T202 inhibits the electrostatic discharge from entering the flash memory device.

20 Second, when an integrated circuit is active, the inhibiting signal S206 may present a low voltage level at the gate and thereby the input stage T202 inhibits the input signal S204 at the source from being transferred to the drain. Suppose that during operation of the flash memory device, a large voltage is presented by design via input signal S204 to transition the integrated circuit into a test mode. Other circuitry, which will be discussed hereinafter, brings the inhibiting signal S206 to a
25 low voltage level and thereby inhibits the signal S204 from entering the integrated circuit, such as a flash memory device.

What has been shown hereinbefore is that the input stage T202 operates to selectively inhibit a voltage from entering an integrated circuit whether the

integrated circuit is active or inactive. As discussed, such a behavior is useful to resist certain voltages that may ruin low-voltage transistors having thin gate-oxides.

5 The input buffer 200 includes a transistor T206 having a gate, a drain, a source, and a bias. In one embodiment, the transistor T206 includes a p-channel transistor. The term "bias" means the inclusion of a substrate bias that is used to inhibit undesired body effects. The gate of the transistor T206 couples to the node E and is therefore receptive to the inhibiting signal S206. The drain and the bias of the transistor T206 couple to the node C.

10 The input buffer 200 includes a transistor T204 having a gate, a drain, a source, and a bias. In one embodiment, the transistor T204 includes a p-channel transistor. The gate of the transistor T204 couples to the node E and is also therefore receptive to the inhibiting signal S206. The drain of the transistor T204 couples to a resistor R204. In one embodiment, the resistor R204 is about 0.203×10^3 ohms. The drain of the transistor T204 couples to the drain of the transistor
15 T206. The bias of the transistor T204 couples to the source of the transistor T204. The resistor R204 couples to a voltage supply.

The purpose of the transistors T204 and T206 is to prevent the node C from floating. These two transistors are turned on when the inhibiting signal S206 is at a low voltage signal. Node C will be at a high voltage level when these two
20 transistors are turned on thereby preventing the node C from floating.

A third clamping circuit C206 couples to the node C. The third clamping circuit C206 includes an n-channel transistor T208 having a gate, a drain, and a source. The gate of the n-channel transistor T208 couples to a resistor R206. In one
25 embodiment, the resistor R206 is about 0.249×10^3 ohms. The resistor R206 couples to ground. The drain of the n-channel transistor T208 couples to a metal option M202. The metal option M202 couples to the voltage supply. In one embodiment, the metal option M202 can be removed so as to inactivate the third clamping circuit C206. The source of the n-channel transistor T208 couples to the

node C.

A fourth clamping circuit C208 also couples to the node C. The fourth clamping circuit C208 includes an n-channel transistor T216 having a gate, a drain, and a source. The gate of the n-channel transistor T216 couples to the source, the drain couples to the node C, and the source couples to ground.

These two clamping circuits, C206 and C208, help to enhance a charge-device-model test that is applied to an integrated circuit, such as a low-voltage memory device that includes the input buffer 200. In one embodiment, the charge-device-model test is a test that complies with EIA/JEDEC standards. One of these standards includes EIA/JEDEC, Test Method C101: Field-Induced Charged-Device Model Test Method for Electrostatic Discharge Withstand Thresholds of Microelectronic Components (May 1995).

The input buffer 200 includes an output stage I202 having a first connection and a second connection. The first connection couples to node C and the second connection couples to node D. The first connection receives the input signal S204 presented at node C and the second connection presents an inverted signal S204 as signal S212. The signal S212 progresses to other circuitry (not shown) of the integrated circuit, such as a low-voltage flash memory device.

In one embodiment, the output stage I202 is an inverter I202 having the first connection and the second connection as discussed hereinbefore. The inverter I202 includes an n-channel transistor T214 having a gate, a drain, and a source. The gate of the n-channel transistor T214 couples to the node C, the drain couples to the node D, and the source couples to ground.

The inverter I202 further includes a p-channel transistor T212 having a gate, a drain, and a source. The gate of the p-channel transistor T212 couples to the node C. The drain of the p-channel transistor T212 couples to the node D. Therefore, the gate of the n-channel transistor T214 and the gate of the p-channel transistor T212 define the first connection. The drain of the n-channel transistor T214 and the drain

of the p-channel transistor T212 define the second connection.

The input buffer includes an enabling transistor T210. The enabling transistor T210 is a p-channel transistor having a gate, a drain, and a source. The gate of the enabling transistor T210 couples to an enabling signal S202. In one embodiment, the enabling signal S202 is low. Therefore, the enabling transistor
5 T210 is turned on. The source of the enabling transistor T210 couples to the voltage supply. The drain of the enabling transistor T210 couples to the drain of the p-channel transistor T212 of the inverter I202.

The enabling transistor, being turned on, keeps the inverter I202 active
10 because current can flow from the voltage supply to the drain of the enabling transistor T210 and to the inverter I202. The inverter I202 produces the signal S212 at a low level at node D when the input signal S204 is at a high level at the node C. This is the result because the n-channel transistor T214 is turned on while the p-channel transistor T212 is turned off when the input signal S204 is at a high level.
15 The p-channel transistor T212, being turned off, disconnects the node D to the voltage supply. Instead the node D connects to ground via the n-channel transistor T214, which is turned on. Ground defines a logic low level, and hence the signal S212 is at a low level.

When the input signal S204 is at a low level, the opposite happens. The n-channel transistor T214 is turned off, and the p-channel transistor T212 is turned on.
20 The p-channel transistor T212, being turned on, connects the node D to the voltage supply. The voltage supply defines a logic high level, and hence the signal S212 is at a high level.

Figure 3 is a circuit diagram according to an embodiment of the present invention. A voltage sensor 300 includes a multiple of stages: a triggering stage
25 302, a first inverting stage 304, a delay stage 306, and a second inverting stage 308. Depending on the voltage level of the input signal S304, the voltage sensor 300 may trigger. The input signal S304 is similar to the input signal S104 as discussed

hereinbefore. A sensed signal S308, which is produced by the voltage sensor 300, reflects whether the voltage sensor 300 was triggered.

The triggering stage 302 includes a first portion 302₁. The first portion 302₁ is receptive to the input signal S304. The input signal S304 passes through a metal option M302. The metal option M302 may be removed to inactivate the voltage sensor 300. The input signal S304, having passed through the metal option M302, is presented at node A.

The first portion 302₁ includes a p-channel transistor T302 having a gate, a drain, a source, and a bias. The gate of the p-channel transistor T302 couples to a resistor R302. In one embodiment, the resistor R302 is about 1.024×10^3 ohms. The source of the p-channel transistor T302 couples to the node A and is receptive to the input signal S304. The drain of the p-channel transistor T302 couples to the resistor R302 and a node B. The bias of the of the p-channel transistor T302 couples to the node A. A metal option M304 couples to the drain and the source of the p-channel transistor T302. Current will flow through the metal option M304 instead of through the transistor T302 when the metal option M304 is inserted. This is the case because current seeks a path that has the least resistance.

The first portion 302₁ includes a p-channel transistor T304 having a gate, a drain, a source, and a bias. The gate of the p-channel transistor T304 couples to the resistor R304. In one embodiment, the resistor R304 is about 1.024×10^3 ohms. The source of the p-channel transistor T304 couples to the node B. The drain of the p-channel transistor T304 couples to the resistor R304 and a node C. The bias couples to the node A. A metal option M306 couples to the drain and the source of the p-channel transistor T304. Current will flow through the metal option M306 instead of through the transistor T304 when the metal option M304 is inserted.

The first portion 302₁ includes a p-channel transistor T306 having a gate, a drain, a source, and a bias. The gate of the p-channel transistor T306 couples to a resistor R306. In one embodiment, the resistor R306 is about 1.024×10^3 ohms.

The resistor R306 couples to the voltage supply. The source of the p-channel transistor T306 couples to the node C, the drain couples to the node D, and the bias couples to node A.

5 The p-channel transistor T306 is generally turned off because its gate couples through the resistor to the voltage supply, which is a logic high level. To turn on the p-channel transistor T306, the voltage at node C must be greater than the sum of the threshold voltage (V_{TR}) of the p-channel transistor T306 and the voltage presented at the gate of the p-channel transistor T306 (V_{cc}). Thus, a voltage at node C that turns on the p-channel transistor T306 is defined as the triggering voltage.

10 This triggering voltage can be considered as the voltage that triggers the voltage sensor 300.

The voltage at node C is derived from the voltage at node A. The voltage at node A is derived from the input signal S304. Thus, the input signal S304 can provide the triggering voltage if the input signal S304 is sufficiently high, such as

15 the sum of V_{cc} and V_{TR} . The triggering voltage can be increased by an additional V_{TR} if the metal option M306 is removed. When the metal option M306 is removed, the current must flow through the p-channel transistor T304. A voltage drop across the source and the drain is created by the flow of current across the p-channel transistor T304. This voltage is about one V_{TR} . The triggering voltage can be

20 further increased to an additional V_{TR} by removing the metal option M304. Thus, the metal options M304 and M306, together, can increase the triggering voltage to the sum of V_{cc} and three V_{TR} 's.

The triggering stage 302 includes a second portion 302₂. The second portion 302₂ is receptive to a pumped signal S306. The pumped signal S306 is similar to

25 the pumped signal S106 as discussed hereinbefore. The pumped signal S306 is presented to an n-channel transistor T308 having a gate, a drain, and a source. The gate of the n-channel transistor T308 is receptive to the pumped signal S306, the drain couples to the node C, and the source couples to the node E.

The second portion 302₂ includes a number of n-channel transistors: T310, T312, T314, T316, and T318. Each of these n-channel transistors includes a gate, a drain, and a source. The gate of the n-channel transistor T310 is receptive to the signal S306, the drain couples to the node E, and the source couples to node F. A metal option M308 couples to the drain and the source of the n-channel T310. The gate of the n-channel transistor T312 is receptive to the signal S306, the drain couples to the node F, and the source couples to node G. A metal option M310 couples to the drain and the source of the n-channel T312. The gate of the n-channel transistor T314 is receptive to the signal S306, the drain couples to the node G, the source couples to node H. A metal option M312 couples to the drain and the source of the n-channel T314. The gate of the n-channel transistor T316 is receptive to the signal S306, the drain couples to the node H, and the source couples to node I. A metal option M316 couples to the drain and the source of the n-channel T318. The gate of the n-channel transistor T318 is receptive to the signal S306, the drain couples to the node I, and the source couples to node J. A metal option M316 couples to the drain and the source of the n-channel T318.

Each of the metal options, M308 to M316, can be removed to decrease the tripping voltage by 50 millivolts, or can be inserted to increase the tripping voltage by the same amount, which is 50 millivolts. A logic high signal is presented to the node D to progress through subsequent stages 304 to 308 if the input signal S304 is sufficiently high to trigger the trigger stage 302. Otherwise, a logic low signal is presented to the node D.

The voltage sensor 300 includes the first inverting stage 304. The first inverting stage 304 includes a first inverter I302 and a second inverter I304. The first inverter I302 includes an n-channel transistor T322, having a gate, a drain, and a source, and a p-channel transistor T320, having a gate, a drain, a source, and a bias. The gate of the n-channel transistor T322 couples to the node D, the drain couples to a node K, and the source couples to ground. The gate of the p-channel

transistor T320 couples to the node D, the source couples to the voltage supply, the drain couples to the node K, and the bias couples to the voltage supply. The second inverter I304 includes an n-channel transistor T326, having a gate, a drain, and a source, and a p-channel transistor T324, having a gate, a drain, a source, and a bias. 5 The gate of the n-channel transistor T326 couples to the node K, the drain couples to the node L, and the source couples to ground. The gate of the p-channel transistor T324 couples to the node K, the source couples to the voltage supply, the drain couples to the node L, and the bias couples to the voltage supply.

The inverter I302 of the first inverting stage 304 will invert the logic signal, 10 which is presented at node D. The logic signal will be inverted again by the inverter I304 of the first inverting stage 304. Thus, the logic signal, which is presented at node D, will be presented in the same logic level at node L.

The voltage sensor 300 includes the delay stage 306 having a number of energy-storing devices: D302, D304, D306, and D308. Each of the energy-storing 15 devices, D302 to D308, is fabricated as a transistor having a gate, a drain, and a source. The energy-storing device D302 includes a p-channel transistor T328 that couples its gate to a node M and its drain and source to the voltage supply. A metal option M318 couples to the node M as well as to the voltage supply. Another metal option M320 couples to the node M and the node L. The energy-storing device 20 D304 includes a p-channel transistor T330 that couples its gate to a node N and its drain and source to the voltage supply. A metal option M326 couples to the node N as well as to the voltage supply. Another metal option M328 couples to the node N and the node L. The energy-storing device D306 includes an n-channel transistor T332 that couples its gate to a node O and its drain and source to ground. A metal 25 option M324 couples to the node O as well as to ground. Another metal option M322 couples to the node O and to the node L. The energy-storing device D308 includes an n-channel transistor T334 that couples its gate to a node P and its drain and source to ground. A metal option M322 couples to the node P as well as to

ground. Another metal option M330 couples to the node P and the node L.

The logic signal, which is presented at node L, will be delayed by the delay stage 306. The delay stage 306 serves to reject undesired noise in the logic signal. The duration of the delay is dependent on the number of active energy-storing devices D302 to D308. The metal options M320, M328, M322, and M330 can be removed, to inactivate, or be inserted, to activate, the energy-storing devices D302, D304, D306, and D308, respectively. The metal options M318, M326, M324, and M330 can be removed to float the node M, N, O, and P, respectively. The metal options M318, M326, M324, and M330 can be inserted to bring the node M, N, O, and P high so as to allow a shorter delay for noise rejection.

The voltage sensor 300 includes a second inverting stage 308. The second inverting stage 308 includes an inverter I306 and the inverter I308. The inverter I308 presents a sensed signal S308. After being delayed by the delay stage 306, the logic signal is inverted by the inverter I306 and inverted again by the inverter I308. Hence, the logic signal, which is presented at node L, is at the same logic level after it passes through inverter I308. The logic signal, having passed through inverter I308, is also known as a sensed signal S308. The sensed signal S308 is similar to the sensed signal S108, which is discussed hereinbefore. The sensed signal is at a high logic level when the voltage sensor 300 is triggered. Otherwise, the sensed signal is at a low logic level.

Figure 4 is a circuit diagram according to an embodiment of the present invention. An inhibiting circuit 400 selectively produces an inhibiting signal S410. The inhibiting signal S410 is similar to the inhibiting signal S110 as discussed hereinbefore. The inhibiting circuit 400 is receptive to a sensed signal S408. The sensed signal S408 is presented to a node D.

An inverter I402 couples to the node D to receive the sensed signal S408. The inverter I402 inverts the sensed signal S408 and presents the sensed signal S408, which is now inverted, to an n-channel transistor T406. The n-channel

transistor T406 includes a gate, a drain, and a source. The gate of the n-channel transistor T406 receives the sensed signal S408, which is inverted, the drain couples to the node B, and the source couples to ground.

5 The n-channel transistor T406 is turned on when the inverted sensed signal is at a high logic level. Thus, the sensed signal S408, prior to the inversion, is at a low logic level. The sensed signal S408, at a low logic level, reflects that the voltage sensor circuit (not shown), which precedes the inhibiting circuit 400, did not trigger.

10 The p-channel transistor T404 is also turned on when the n-channel transistor T406 is turned on. The p-channel transistor T404 includes a gate, a drain, a source, and a bias. The gate of the p-channel transistor T404 couples to the node B, the source couples to the node A, the drain couples to the node C, and the bias couples to the node A. The node A presents a pumped signal S406. The pumped signal S406 is similar to the pumped signal S106, which is discussed hereinbefore. The reason the p-channel transistor T404 is turned on is because the n-channel
15 transistor, when turned on, pulls the gate of the p-channel transistor T404 at node B to ground, which is a low logic signal. The node C is also pulled high to the level of the pumped signal S406 via the source and drain of the p-channel transistor T404. Because the node C presents the inhibiting signal, when the node C is at a high logic level, the inhibiting signal is at a high logic level.

20 Returning to node D, the inhibiting circuit includes an n-channel transistor T408 having a gate, a drain, and a source. The gate of the n-channel transistor T408 couples to the node D, the drain couples to the node C, and the source couples to ground. When the node D presents the sensed signal S408 at a low logic level, the n-channel transistor T406 is turned on as discussed hereinbefore, but the n-channel
25 transistor T408 is turned off.

When the node D presents the sensed signal S408 at a high logic level, the n-channel transistor T408 is turned on, but the n-channel transistor T406 is now turned off. The node C is pulled low by the n-channel transistor T408. The p-channel

transistor T404 is turned off because the node C presents a low logic level to the p-channel transistor T402, which turns on the p-channel transistor T402. The p-channel transistor T402 includes a gate, a drain, a source, and a bias. The gate of the p-channel transistor T402 couples to the node C, the source couples to the node A, the drain couples to the node B, and the bias couples to the node A. The source and drain of the p-channel transistor T402 pull node B high to the level of the pumped signal S406 when the p-channel transistor T402 is turned on. When node B is at a high logic level, transistor T404 is turned off.

What has been shown is that the inhibiting signal S410 depends on the sensed signal S408. The inhibiting signal S410 is at the voltage level of the pumped signal S406, which is about 5 volts, when the sensed signal S408 is at a low logic level. The inhibiting signal S410 is at a low logic level when the sensed signal S408 is at a high logic level. The sensed signal S408 is at a high logic level when the voltage sensor (not shown) is triggered.

One use of the inhibiting signal S410 at a low logic level includes support for a special manufacturing mode. The inhibiting signal S410, at a low logic level, can be used to inhibit high voltages from affecting thin gate-oxide transistors residing beyond the input buffer. However, at the same time, such high voltages can be input into the integrated circuit housing the input buffer so that the special manufacturing mode is supported.

Figure 5 is a block diagram according to one embodiment of the present invention. A wireless device 500 includes a display 502, a processor 504, and a low-voltage flash memory device 506. The display 502 provides a user interface that can be navigated by a user to control the wireless device 500. The processor 504 processes data and control provided by the user or a remote server (not shown). The low-voltage flash memory device 506 provides storage to store data and controls. In one embodiment, the low-voltage flash memory device 506 includes a multiple of thin gate-oxide transistors, and an input buffer as discussed hereinbefore.

The wireless device 500 is selected from a group consisting of a cellular phone, a personal appliance, and an Internet appliance.

Conclusion

5 Systems, devices, and methods have been discussed to inhibit semiconductor
breakdown of thin gate-oxide transistors. These thin gate-oxide transistors may be
used in 32-megabit integrated circuits, such as flash memory. Previous generations
of integrated circuits use a power supply in the range of 2.7 to 5 volts. The
embodiments of the present invention focus on integrated circuits that use a power
10 supply in the range of 1.65 volts to 2.22 volts. To guarantee the same timing
behavior as previous generations of integrated circuits, low-voltage integrated
circuits use thin gate-oxide transistors, such as CMOS. A possibility exists that a
voltage greater than 2.22 volts may be introduced to these thin gate-oxide
transistors. When such a voltage is present, the lifetime of these transistors may be
15 compromised.

The embodiments of the present invention inhibit semiconductor breakdown
of the thin gate-oxide transistors in the presence of voltages greater than 2.22 volts
so that the lifetime is not compromised.

20 Although the specific embodiments have been illustrated and described
herein, it will be appreciated by those of ordinary skill in the art that any
arrangement which is calculated to achieve the same purpose may be substituted for
the specific embodiment shown. This application is intended to cover any
adaptations or variations of the present invention. It is to be understood that the
above description is intended to be illustrative, and not restrictive. Combinations of
25 the above embodiments and other embodiments will be apparent to those of skill in
the art upon reviewing the above description. The scope of the invention includes
any other applications in which the above structures and fabrication methods are
used. Accordingly, the scope of the invention should only be determined with

reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.